# Design of a 1st year Engineering Transfer Program: Creating a Sustainable Learning Environment for Student Success

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*Abstract* - **MacEwan University is a publicly funded institution situated in Edmonton, Alberta and provides a first-year engineering transfer program to over 200 students each year. Due to education funding cutbacks, we are now faced with continually growing class sizes, increased teaching workloads, and rising transfer GPAs. At the same time, the demand for engineers continues to increase in our province. This situation has brought about the need to adapt our engineering program in an attempt to maintain our teaching/learning standards while cutting costs. The focus of our efforts has been on student integration, course inter-connectivity, and sustainable assessment methods. To this end, our institution has integrated a week long engineering preparation workshop, re-evaluated the first year curricula and re-designed a course to promote deeper learning, and are currently developing pedagogical software to provide students with individualized feedback at a crucial stage of the learning process.**

*Index Terms* - Preparation, Assessment, Sustainability, Transferability

## INTRODUCTION

The development of the engineering pedagogy summarized in this paper has relied very heavily on anecdotal evidence and best practices. Although there is a large body of literature devoted to the study of engineering pedagogy, direct application of this information is very difficult since there are so many external factors that influence the educational process: such factors as student capabilities, cultural and regional influences as well as economic influences and local job opportunities. Despite this, there are certainly well described processes that can be used to create a positive environment that will profoundly influence the education of engineering students [1]. The sharing of the knowledge of these best practices is paramount to the future education of engineers. We have adapted our program to deal with three specific challenges: student preparation, course connectivity/integration and novel assessment techniques..

The first challenge for a new student is to develop the ability to quickly change from a high school mentality to that of a first-year engineering student. The student must, essentially acquire skills for time management as well as the capacity to work independently in the exploration of first-year material. If left too long, the student will have to learn the lesson the hard way, and their grades will drop as a result. In response to this need, our program provides a week long “Bootcamp” one week prior to the start of classes to help the students improve the skills and mindset that will be needed as the academic term progresses.

The second effort being made is the inter-connectivity of courses. One way to get a student to grasp material being taught, and to ensure that a "deep" learning (unconscious competence development [2]) is occurring, is to relate it to something that they have already learned. A recent opportunity to re-design a course in the second term of our program has created the opportunity to re-use examples in several courses in different contextual situations in an attempt to help students learn the material in greater depth.

The final effort being done is to re-evaluate the way students are assessed in order to improve the assessment methods, while at the same time making them sustainable. The major focus of these improvements is to provide both students and instructors with instantaneous feedback which can, in turn, enhance the instruction provided to address the learning needs of the individual students. Currently, we have developed software, which will create randomized assignments and generate full solution keys with scaled drawings. We have successfully integrated it into the first-year Engineering Statics course. The automated assessment software portion is currently under development.

## STUDENT PREPARATION

It is well understood that the outcome of any process is strongly influenced by the initial phases. There is no doubt that this is also true in the development of engineers [1]. Moreover, the first year of any engineering program is fundamental in building the educational foundation that will serve to develop the engineering student into an engineer. In much the same way, the introduction to a first-year engineering program is also crucial for the successful transition of the student from first-year into second year and so on. For this reason, our institution created a mandatory one-week preparatory course called “Bootcamp”. The structure of this course is described in a paper summarizing many of the best practices that we have used at our institution over the last fifteen years [3]. Our "Bootcamp" has mixed modes of delivery, ranging from in-class delivery of materials to tours and hands-on computing experiences. The content includes review material from high school to entry level university material used in teaching statics and dynamics. Topics include mathematics, physics, chemistry, time management, library services, computing and several assessment sessions to gauge the students' skill level using concept inventories. We also make use of an introductory session where guest speakers (former first-year students) share their experiences and potential pitfalls to academic success in first-year.

## INTERCONNECTED CURRICULUM

The inter-connectivity of courses provides an opportunity for the student to repeat and improve upon already learned skills, thus strengthening neural pathways, which is thought to aid in the long term memory [2]. A proposed course inter-connectivity schematic is presented in Figure 1 for several common first-year engineering courses taught at our institution.

Here, the arrows represent the capacity for further skill development in courses already taken or currently being taken. For example, the English course provides connectivity to other courses as it provides engineering students opportunity to practice their report writing skills.

Further analysis of the chart is shown in Table 1. Here two trends are found. First, that math courses provide the most skills used in other engineering courses, as expected. The other trend is that engineering computing provides the most potential for developing and honing previously learned skills. This is because the course teaches a programming

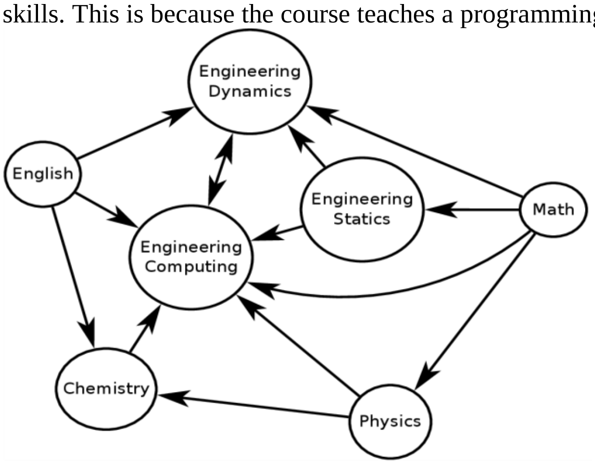



FIGURE 1 - SKETCH SHOWING THE POTENTIAL CONNECTIONS BETWEEN FIRST-YEAR ENGINEERING COURSES.

language which provides the opportunity for many different types of examples pulled from previous courses.

The potential to adapt the engineering curriculum recently came up three years ago when it was decided to change programming languages from C/C++ to MATLAB. The switch resulted in a reduced learning curve that was required to learn the compiler language. This allowed more time in the course to focus on the development of student's higher order thinking and problems solving skills. In addition, the switch from computer science faculty teaching the course to engineering faculty allowed for a more engineer focused course where class assignments focus now on developing previously learned skills to develop memory pathways in the brain. Examples of assignment topics include creating programs to determine area moment of inertia for composite bodies and programs to determine projectile motion.

TABLE 1 - OPPORTUNITIES FOR INTER-CONNECTIVITY IN FIRST-YEAR ENGINEERING COURSES

| Course | Provides Opportunity | Potential Uses |
|---|---|---|
| Engineering Computing | 1 | 6 |
| Engineering Dynamics | 1 | 2 |
| Chemistry | 1 | 2 |
| Engineering Statics | 2 | 1 |
| Physics | 2 | 1 |
| English | 3 | 0 |
| Math | 4 | 0 |

## SUSTAINABLE ASSESSMENT METHODS

Another important factor in the overall competence of an engineering student is the proper assessment of his/her abilities. Current students dubbed the "Generation M" are those who have grown up with the internet, social networking, and peer to peer file sharing technologies [4]. On the web, search engines are becoming smarter, making vast amounts of information available globally. It is now easier to perform an internet search for solutions than to solve the problem independently. In addition to this, solution manuals are easily found on the internet and are being used to directly copy out the solutions. Publishing houses counteract this by changing book editions more frequently, but the questions change only slightly. Instructors need now to change assignments every term to minimize plagiarism. In addition, massively online open courses are emerging as being newer ways to educate. An example is "Engineering Statics" being offered at Coursera [5]. Although not currently offered for credit, these courses suffer from issues on how to assure the proper assessment of students online.

In attempt to tackle some of these issues, software to automatically create assignments and solutions was created by our institution [6]. Although the idea of generating assignments and solutions is not new [7]-[10], the novelty here is creating fully randomized problems (as opposed to a database of statically defined problems) with scaled drawings, variable difficulty levels, and most importantly, with full detailed solutions. An example of a randomly generated question is shown in Figure 2 with its solution shown in Figure 3. For this problem, the masses, the number of rigid bodies, units, and angles are all variable. This creates an unlimited number of problems for practice.

**Problem 2:** [4] Three cables are connected at point C. One cable is attached to the wall at point D. An unkown mass $m$ is attached to a second cable and a third cable passes over a massless, frictionless pulley supported by a pin at B and has a mass attached at the end of the cable at point A. For the condition of equilibrium:

**a)** draw and label the FBD of the pulley wheel at B. [ *1 / 4* ]

**b)** find the magnitude of the mass $m$. [ *3 / 4* ]

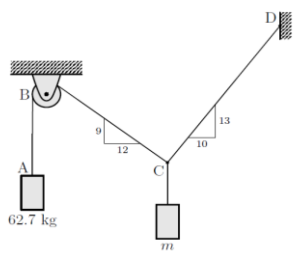
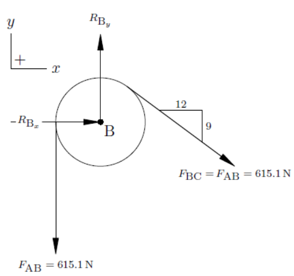



FIGURE 2 - EXAMPLE QUESTION FROM THE RANDOMIZED ASSIGNMENT GENERATOR FOR STATICS

Solution 2: [4]

a) What is the FBD for the pulley pinned at B?




Because the pulley is massless and frictionless, the forces on both sides are equal in magnitude. The angle in which they come off at does not affect the magnitudes. The pulley is still attached at a fixed point, therefore it has reaction forces in order to support itself.

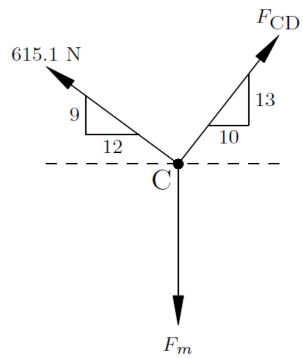
$$F_{AB} = F_{BC}$$
$$F_{AB} = m_A g = (62.7)(9.81) = 615.1$$
$$F_{AB} = 615 \text{ N}$$
$$F_{BC} = 615 \text{ N}$$

b) What is the mass $m$ of the unit attached at point C?

First, if we are going to use the slope triangles instead of calculating the angles then we need to calculate their hypotenuses.

$$\text{hypotenuse} = \sqrt{x^2 + y^2}$$
$$\text{hyp}_{BC} = \sqrt{12^2 + 9^2}$$
$$\text{hyp}_{BC} = 15$$
$$\text{hyp}_{CD} = \sqrt{10^2 + 13^2}$$
$$\text{hyp}_{CD} = 16.40$$

Find $F_{CD}$, then determine $m$.




$$\overset{+}{\rightarrow} \sum F_x = 0$$
$$-615.1\left(\frac{12}{15}\right) + F_{CD}\left(\frac{10}{16.40}\right) = 0$$
$$F_{CD} = 807.1 \text{ N}$$
$$+\uparrow \sum F_y = 0$$
$$615.1\left(\frac{9}{15}\right) + 807.1\left(\frac{13}{16.40}\right) - F_m = 0$$
$$F_m = 1009 \text{ N}$$

Now that we know the force pulling down, and the magnitude of the acceleration due to gravity ($9.81 m/s^2$) we can determine what the mass $m$ is.

$$m = \frac{1009}{9.81} = 102.8 \text{ kg}$$
$$\boxed{m = 103 \text{ kg}}$$

FIGURE 3 - EXAMPLE SOLUTION FROM THE RANDOMIZED ASSIGNMENT GENERATOR FOR STATICS

## RESULTS AND DISCUSSION

We have attempted to implement a pedagogical strategy to optimize teaching resources, enhance learning through course inter-connectivity, and better gauge performance through better assessment techniques. Assessment techniques are used upon entrance to the program to gauges students' capabilities, and at the end of first-year for assessment of knowledge and skills acquired. Currently, the randomized assignments software has been used in the last two sessions of Engineering Statics where it has met with success. Not only do the students appreciate the scaled drawings and full solutions, but the instructors now have more time to spend on developing the course as opposed to creating assignments.

The success of this strategy is difficult, however, to quantify because the process is influenced by numerous often unidentifiable parameters. Sometimes trends in grade point averages (GPAs) may be used to gauge success of various interventions. Figure 4 shows trends in the average GPA (4.0 scale) over an eight year period for MacEwan students at the completion of their first year of engineering as well as the same students' GPAs as they finish their second year at a different institution [3]. The average GPA for the students, in both cases, increases over time. Whether or not this is indicative of improved performance or grade inflation is not clear. It may be coincidental that this increase in GPA corresponds to a substantial change in (improvements to) the curriculum of our engineering computing course. A more disappointing trend is the drop in GPA between first and second year, which has increased substantially in the last two years in particular. This is undesirable as it indicates that students, on average, do not perform as well in second year at their transfer institution as they did in first year at our institution. Since many other changes occurred simultaneously during this time period (increased enrollment and increased faculty resources), it is difficult to gauge the relative contribution of each change. Future research may be able to better quantify the progress of our efforts at our institution.

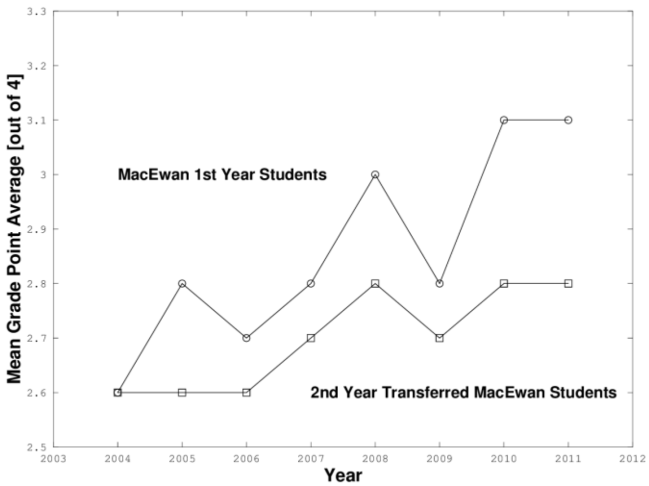



FIGURE 4 - GRAPH OF SECOND-YEAR GPA VS. YEAR

### ACKNOWLEDGMENTS

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